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APPLICATION NUMBER: *60/138,895*

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JC583 U.S. PTO 06/11/99

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# PROVISIONAL APPLICATION FOR PATENT COVER SHEET (Small Entity)

**This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53 (c).**

**INVENTOR(S)/APPLICANT(S)**

| Given Name (first and middle [if any]) | Family Name or Surname | Residence (City and either State or Foreign Country) |
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| Daniel | Kopf | Walgaustrasse 9, A-6832 Roethis, Austria |

☐ *Additional inventors are being named on page 2 attached hereto*

**TITLE OF THE INVENTION (280 characters max)**

Long Life Laser Concept

**CORRESPONDENCE ADDRESS**

*Direct all correspondence to:*

☐ Customer Number ______ → *Place Customer Number Bar Code Label here*

*OR*

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**ENCLOSED APPLICATION PARTS (*check all that apply*)**

| | | | |
|---|---|---|---|
| ☒ Specification | *Number of Pages* 7 | ☒ Small Entity Statement | |
| ☒ Drawing(s) | *Number of Sheets* 6 | ☒ Other (specify) | General Authorization to Charge Fees |

**METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT (*check one*)**

☒ A check or money order is enclosed to cover the filing fees

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The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

☒ No.

☐ Yes, the name of the U.S. Government agency and the Government contract number are: ______

*Respectfully submitted,*

SIGNATURE M. Robert Kestenbaum  Date June 11, 1999

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## USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

*SEND TO: Box Provisional Application, Assistant Commissioner for Patents, Washington, DC 20231*

# Long Life Laser Concept

**Abstract**: This invention relates to the field of lasers and optics where the laser beam passes through or is reflected from the surface of a material which has limited durability under light exposure. A simple technique moves the spot across the material, which enhances the lifetime of the laser or optical system since more than one spot of the same material is used. This technique may be used in combination with material being used inside a laser cavity as well as outside the laser cavity, or in general in any application where high intensity light is exposed to part of an optical material.

The second object of this invention relates to optics holders. An optics holder which is both simple and stable is described. The holder is simple because it only uses a minimum of screws: for example one set screw and one fixing screw but no adjustment screws. Still the holder allows for adjustment of both the vertical and the horizontal angle of the optics within a certain range. The holder is stable because it relies on a double-V-groove supporting technique, which holds the optics in place in a pre-determined way unaffected from machining tolerances.

**Motivation/Background of the invention**: Solid state optical materials, such as for example the solid state laser materials or non-linear optical materials, are usually interesting for several among the following reasons. They can come in small sizes, can withstand high intensities on a spot, can be manufactured in high quantities, and are easy to handle because they are solid (in comparison to, for example, liquid dyes or gases). However, in some cases these materials do not live for extended times when being exposed at a certain light intensity. This can occur, for example, when a nonlinear crystal is used to frequency-convert the laser light, where the laser beam is usually focused onto a small spot or has high peak powers. Similarly, semiconductors may show long-term degradation effects which can limit the time of use of semiconductor materials when exposed to a certain intensity on a spot. Any kind of other optical elements may suffer from similar effects. The goal of this invention is to use up all or a substantial fraction of the available material and not only the material at a fixed spot in the material. Instead of moving the material transversely to the incident light beam and thereby moving the light spot to another position inside the material, we describe here a very simple technique to move the spot on the material in order to allow the use of different spots on the material.

As for the optics holder, the goal is to make simple, easy-to-manufacture, and easy-to-use optics holders. Of special interest are laser mirror holders which are cost-effective, use a minimum of adjustables while still allowing for a certain degree of adjustability.

**<u>State of the art</u>:**

*Nonlinear optics*: Many nonlinear optical crystals that are used for frequency conversion have limited usability when being exposed to light of a certain intensity. For example, the well-know crystal potassium titanyl phosphate ($KTiOPO_4$, KTP) has been reported to suffer from long-term degradation effects, all of which are still under investigation and one of which was called "grey tracking". On the market, many Neodymium-based laser sources that are converted into the green by second harmonic generation use KTP as the doubling crystal, whether intra cavity or extra cavity, and have shown limited long-term operation due to the KTP crystal degradation properties under light exposure. Long-term degradation is often also reported for nonlinear crystals which are used to convert (laser) light into the ultra violet. For example, beta-barium borate, know as BBO, is well know for this application but has shown long-term degradation effects over a time duration on the order of 100 or 1000 hours. In some cases, the problem was solved by transversely moving the crystal with respect to the incident beam, which results in a different spot being "used up". The disadvantage, however, is that usually the crystal has to be moved while keeping its angle orientation constant at very high precision to ensure optimum frequency conversion efficiency. This has often to be done by relatively expensive translation stages.

*Semiconductor materials and surfaces*: Semiconductors usually have lower optical damage thresholds than other solid state optical materials such as laser crystals or optical glass. Also well known is the limited life time of laser diodes which stems from both bulk material and surface degradation, again showing that the issue of long-term degradation is apparent in semiconductors. Semiconductor materials are also used for ultra short pulse generation from lasers, particularly solid state lasers. Such devices are for example the SESAMs (semiconductor saturable absorber mirrors), which were demonstrated to generate pulses at various wavelengths from a variety of laser systems. In some publications, their limited life time and optical degradation on the spot being exposed by the laser beam was pointed out. Again, transversely moving the SESAM to another position such that a "fresh", unused spot is being used would enhance the laser life time by a factor corresponding to as many times as the SESAM can be moved. However, the translation stages used for this purpose may again have unwanted disadvantages such as high cost and big size. Alternatively, these devices may have to be replaced from time to time.

*Linear and other optical materials*: Aside from the materials listed above, similar degradation effects are also apparent in any kind of optical materials, depending on type of material, incident intensity and / or peak intensity, temperature of the material, incident light wavelength, etc. For example, ultra violett wavelengths tend to damage many optical

materials over time if a certain intensity is reached. Also in these cases, the solution that has been presented so far has usually been the replacement of the material after usage or the transverse movement.

*Mirror holders and optics holders:* The mirror holders that are being used most commonly still use an adjustment screw for each axis that can be adjusted. In addition comes a set screw which holds the mirror in place. Finally, such standard mirror holders are fixed to the optics platform or to a post with a fixing screw. Mirror holders of this type can be found in the repertoire of most opto-mechanical components vendors. However, the number of screws, which gives the freedom to make all the adjustments, comes at the expense of increased cost, more complicated assembly procedures, and a higher risk of failure during long-term operation. Therefore, a mirror holder would be useful which uses a minimum of screws and adjustables while still being adjustable within a certain range until all screws are locked in place.

**Description of the invention:**.

*Scheme I*: The proposed scheme I of this invention is shown in figure 1. Here we have used a reflective optical material which is exposed by incident light being imaged or focused through a lens. If the incident beam before the lens is collimated, the lens will cause a focus approximately at the optical material (depending on the degree of collimation), in which case the optical material is positioned approximately at a distance corresponding to the focal length f away from the lens. If we now put a reflective mirror M1 before the lens in a distance which corresponds to about the focal length of the lens, then we can move the spot on the laser material simply by adjusting the angle of the reflecting mirror M1. If M1 is positioned at a distance corresponding exactly to f away from the lens, the beam propagation axis after the lens (before the optical material) does not change its angle at all. Then any change in angle is directly changed into a movement of the light spot on the optical material without affecting the beam angle. Therefore, the mechanical tolerances for M1 are uncritical while the beam propagation axis angle stays highly constant.

The scheme shown in Figure 1 can for example be used inside a laser resonator, i.e. intra cavity. In a standing wave laser resonator, the scheme of Figure 1 can be one end of the cavity, in which case the optical material preferably is adjusted such that it reflects the beam back onto itself, corresponding to the lasing condition. Alternatively, in a linear or ring resonator configuration, the propagation axis does not necessarily have to be perpendicular to the optical material reflecting surface. The scheme of Figure 1 can be used, for example, in combination with a SESAM (semiconductor saturable absorber mirror) as the optical material.

Any degradation effect on one spot after some time can be circumvented when tilting the angle of M1 and thereby moving to another spot. This adjustment of M1 does not or does not substantially affect the laser alignment, since the lasing condition is still fulfilled (back reflection onto itself). Therefore, M1 has the special property of not affecting the laser alignment, but only the position of the spot on the optical material or the SESAM. Given a sufficiently large SESAM area, this can result in a susbantial enhancement of the SESAM and thus laser system lifetime.

In Figure 2 we show a possible way to use this scheme for frequency conversion in combination with a nonlinear crystal positioned close to the focus of the incident beam after the lens. In this case the beam passes through the nonlinear crystal and is reflected back onto itself, for example by a reflective surface on the crystal back side (as in the figure 2) or by a separate reflector (not shown). The orientation of the nonlinear crystal, its cut and length can be determined by standard rules well known in the nonlinear optics literature. Given the incident beam parameters and the focal length of the lens, the beam parameters at the crystal can be determined using standard optics calculation formulas and are useful to determine the crystal parameters for optimum frequency conversion, as described in the nonlinear optics literature. In the scheme of figure 2, the frequency-converted beam propagates back after passing M1 again along the same axis as the incident beam, and then may be separated from the incident beam by using, for example, a dichroic mirror, or a polarizing beam splitter. Likewise, this scheme has the advantage that regardless of the tilt of M1 and therefore regardless of the spot being used on the optical material, the back-reflected beam does not change its direction and properties. If, however, the two beams are chosen not to be on the same axis, there may be other means to separate them from each other, such as for example a mirror edge.

In figure 2 we have neglected any walk-off that may occur inside the optical material between the fundamental (i.e. incident) and the frequency-converted beam, which results in the two beams being on the same axis. However, the same scheme can be used if (even strong) walk-off is apparent because the frequency-converted beam and the fundamental beam will still be on axis, as shown in Figure 3. The frequency-converted beam travels along a different axis inside the nonlinear optical material. All beams, however, exit the material on parallel axes, as shown in the Figure 3. The back-traveling beams finally are combined on the same axis after they exit the front side of the material. The same considerations apply when the reflecting surface is directly attached to the crystal back side and perpendicular to the incident beam axis. Also, these considerations apply for any kind of birefringend optical material and are not necessarily limited to nonlinear optical materials.

Generally, in all schemes described above and shown in the figures the lens can also be replaced by a reflective mirror with corresponding focal length. Likewise, the lens or reflective focusing mirror does not have to be spherical, as would be most common in many applications. But it could also be a cylindrical lens or a cylindrical focusing mirror, in which case all considerations above only apply in one transverse direction. Also, the lens does not have to be a plano-concave lens, as depicted in all figures for simplicity, but it could be any kind of focusing means. For example, achromatic lenses, doubletts, cylindrical lenses, parabolic mirrors, and many more would apply. Aberration corrected lenses and parabolic mirrors would even have advantages in a sense that the off-axis angle aberrations can be reduced in comparison to other types of lenses.

Any features depicted in the figures may be put together in arbitrary combinations. Within the scope of this invention, the skilled optics and laser engineer and scientist can also come up with features substantially the same as the ones described here.

Figure 4 shows the technical drawing of one possible setup of a simple and stable optics holder, which uses only two screws. The holder is machined out of a solid aluminum block. Other materials may also be suitable. The machining may be done from three sides. The holder described in Figure 4 is designed for holding an optics component or laser mirror with 12.7 mm diameter and 9.5 mm length, but is not limited to these dimensions. Alternatively, the holder can be made substantially smaller or larger. The hole H1 holding the laser mirror has a diameter somewhat larger than 12.7 mm, for example 13.5 mm, except for the elevated section on which the mirror is going to sit on. The hole H2 divides these sections into the four labeled touching surfaces, which are pointed out bold in Figure 4. The optics component, when moved into the hole H1, will be resting on these four defined touching surfaces in a defined way. The optics component may be chosen to have one or both surfaces wedged. Then the rotation of the component around its axis, as indicated in Figure 4 with the circled arrow to the right, results in a fine change of the vertical angle of the wedged surface. This is how it is possible to do a vertical angle fine tuning on the wedged surfaces before the set screw on the top of the holder is fixed. Once the vertical angle and the set screw are fixed, the holder can still be horizontally rotated and adjusted, and finally be fixed to the optics platform or post with the second screw.

The optics component can, for example, be a laser mirror where the wedged surface is coated with a reflective coating for the wavelength of interest. Also, the optics component could be used in transmission rather than in reflection, in which case the surface angle can again be pre-tuned due to a wedge. Any other optics materials can be used similarly.

Another possible setup is shown in Figure 5. Here the sections on which the optics component sits are not divided into four. There are two parallel sections which are supporting the optics component, as indicated in Figure 5 with bold lines. This type of optics holder has the advantage of being particularly simple to manufacture. It can be manufactured by machining action from only two sides.

Figure 6 shows a third alternative where the hole H1 is a simple hole with no supporting section sticking out like in the previous two versions. This hole can then be made such that the optics component tightly fits, with the set screw holding the component in place. Alternatively, glue may be used instead or in addition to the set screw. If only glue is used, this results in a mirror holder which only requires a single screw for mounting to the optics platform. Before the glue is dried, it is still possible to vertically adjust the angle of the wedged surface by rotating the optics component around its axis.

Generally, all features mentioned above may be combined in arbitrary ways. Also, any features of state-of-the-art optics holders may be combined with features of this invention.

<u>**Application examples**</u>:

This invention can be used in laser or optical systems. In particular, if such systems contain an optical material which degrades with time under light exposure, this invention may be a simple solution as to how to increase the overall lifetime of the laser or optics system. As an example, in a typical laser using a SESAM for the generation of picosecond or femtosecond pulses, the beam diameter may be on the order of 100 micro meters. The overall area of the SESAM, however, can be much larger than the size of the laser spot. Given a SESAM size of for example 5mm x 5mm, this results in approximately 625 spots that can be used throughout the SESAM surface. This results in 625.000 hours of operation provided that each spot endures about 1.000 hours of operation.

For optical materials that are inhomogeneous, this invention may be used to search for a good spot or avoid bad spots by tilting M1 until the desired spot quality is reached.

Another example is the generation of ultra violet light (UV) according to the setup of Figure 2: To accomplish nonlinear optical frequency conversion from the green into the UV, for example BBO can be used as the optical material in the configuration of Figure 2. M1 is made reflective for both the incident green light and the back-reflected frequency-doubled ultra-violett light. The lens is made transmissive for both wavelengths. The walk-off apparent in BBO is compensated according to the scheme of figure 3. The dichroic mirror can be used to separate the two wavelengths. As an alternative, M1 can be made high transmissive for the UV and reflective for the incident wavelength, in which case M1 would

act as the dichroic mirror. However, then any tilt of M1 would result in changed UV output direction.

If a cylindrical lens or a cylindrical mirror or any other focusing means that only acts in one transverse direction is used, this would generate an asymmetric beam inside the optical material. This can result in a number of advantages: In an optical material such as a nonlinear optical crystal, the different beam properties in the two transverse directions can each separately be well matched to the requirements for optimum frequency conversion according to standard nonlinear optics formulas. For example, the angle acceptance for frequency conversion in an optical material may be higher in the vertical transverse direction than in the horizontal direction, in which case a stronger focusing condition is preferably used in the vertical direction. Likewise, walk-off may occur predominantly in one transverse direction, in which case the focusing condition can also be matched to the walk-off angle. An asymmetric beam inside a vertically squeezed nonlinear optical crystal crystal can result in a one-dimensional heat flow which can increase the thermal load the xtal can take in comparison to radial cooling.

The optical holder described in this invention may be used in combination with the first objective of the invention. For example, it may be used as the holder for the optical material in a setup such as described in Figures 1 to 3.

# VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY STATUS (37 CFR 1.9(f) AND 1.27 (b)) - INDEPENDENT INVENTOR

Docket No. (B) KP34508US

| Serial No. | Filing Date | Patent No. | Issue Date |
|---|---|---|---|
| | | | |

Applicant/ Patentee: KOPF Daniel

Invention:

Long Life Laser Concept

As a below named inventor, I hereby declare that I qualify as an independent inventor as defined in 37 CFR 1.9(c) for purposes of paying reduced fees under section 41(a) and (b) of Title 35, United States Code, to the Patent and Trademark Office with regard to the invention entitled above and described in:

- ☒ the specification to be filed herewith.
- ☐ the application identified above.
- ☐ the patent identified above.

I have not assigned, granted, conveyed or licensed and am under no obligation under contract or law to assign, grant, convey or license, any rights in the invention to any person who could not be classified as an independent inventor under 37 CFR 1.9(c) if that person had made the invention, or to any concern which would not qualify as a small business concern under 37 CFR 1.9(d) or a nonprofit organization under 37 CFR 1.9(e).

Each person, concern or organization to which I have assigned, granted, conveyed, or licensed or am under an obligation under contract or law to assign, grant, convey, or license any rights in the invention is listed below:

- ☒ No such person, concern or organization exists.
- ☐ Each such person, concern or organization is listed below.

*NOTE: Separate verified statements are required from each named person, concern or organization having rights to the invention averring to their status as small entities (37 CFR 1.27)

FULL NAME ____________________
ADDRESS ____________________
☐ Individual ☐ Small Business Concern ☐ Nonprofit Organization

FULL NAME ____________________
ADDRESS ____________________
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I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.28(b))

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

NAME OF INVENTOR KOPF Daniel
SIGNATURE OF INVENTOR Daniel Kopf DATE: 11.6.1999

NAME OF INVENTOR
SIGNATURE OF INVENTOR DATE:

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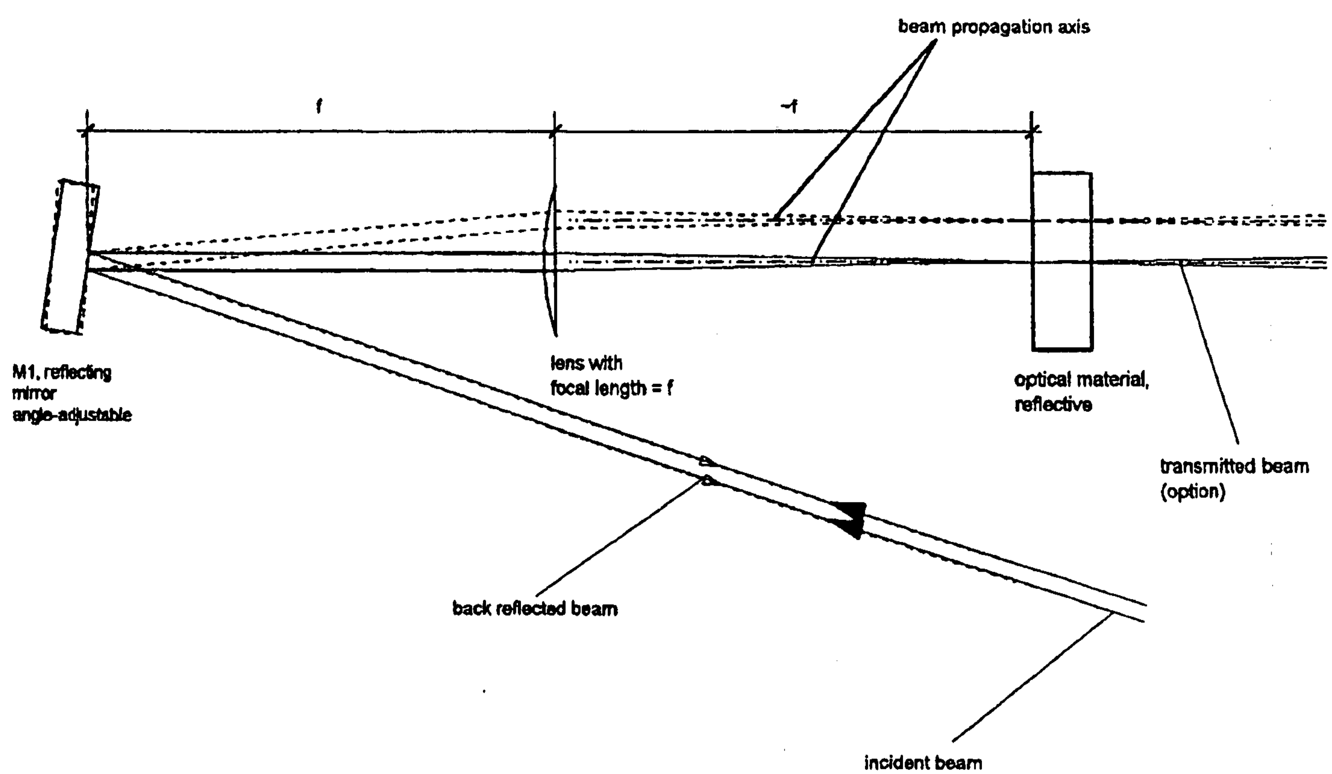


Figure 1 "LLLC - Long Life Laser Concept"

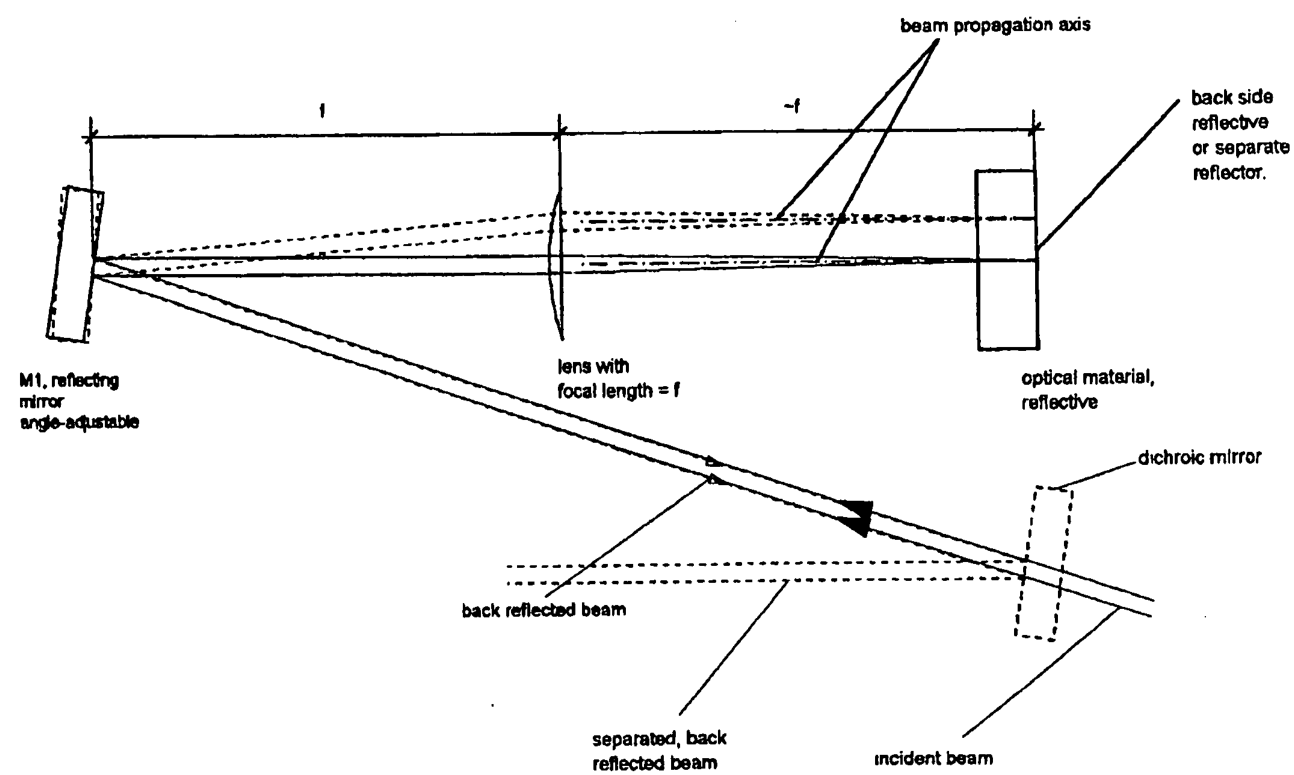


Figure 2 "LLLC - Long Life Laser Concept"

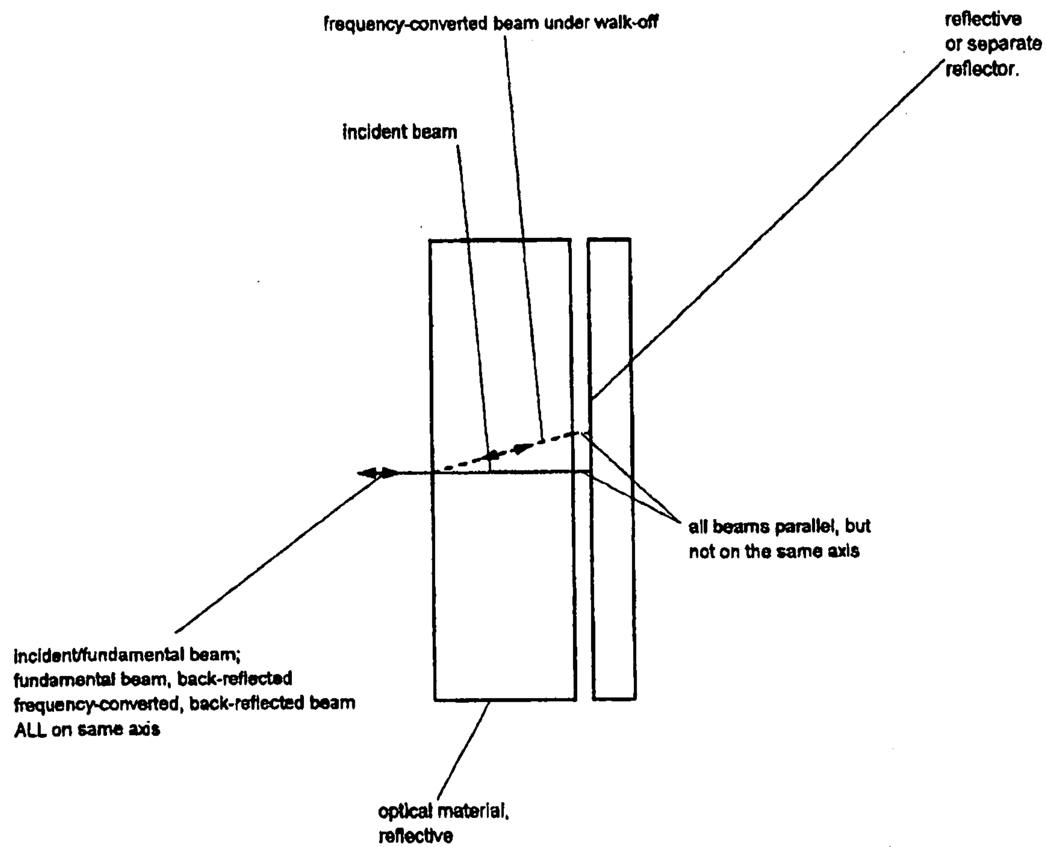


Figure 3 "LLLC - Long Life Laser Concept"

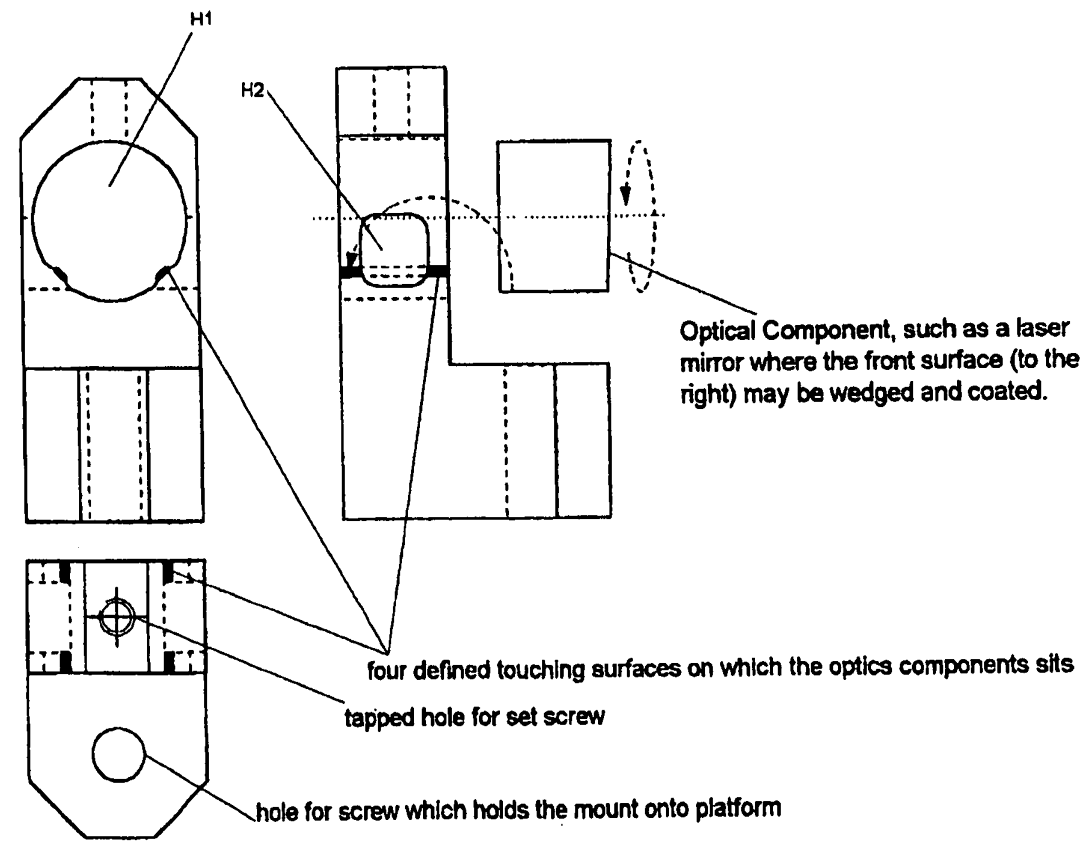


Figure 4 "LLLC - Long Life Laser Concept"

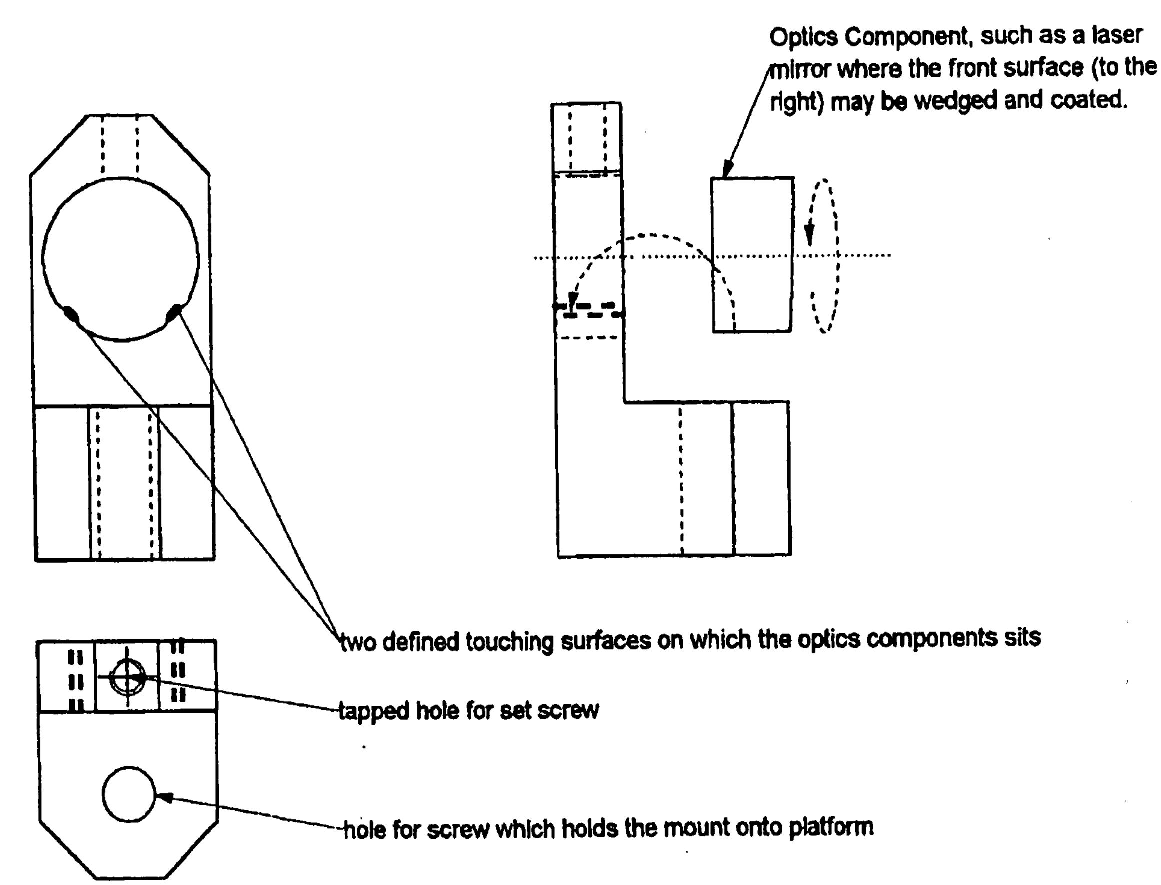


Figure 5 "LLLC - Long Life Laser Concept"

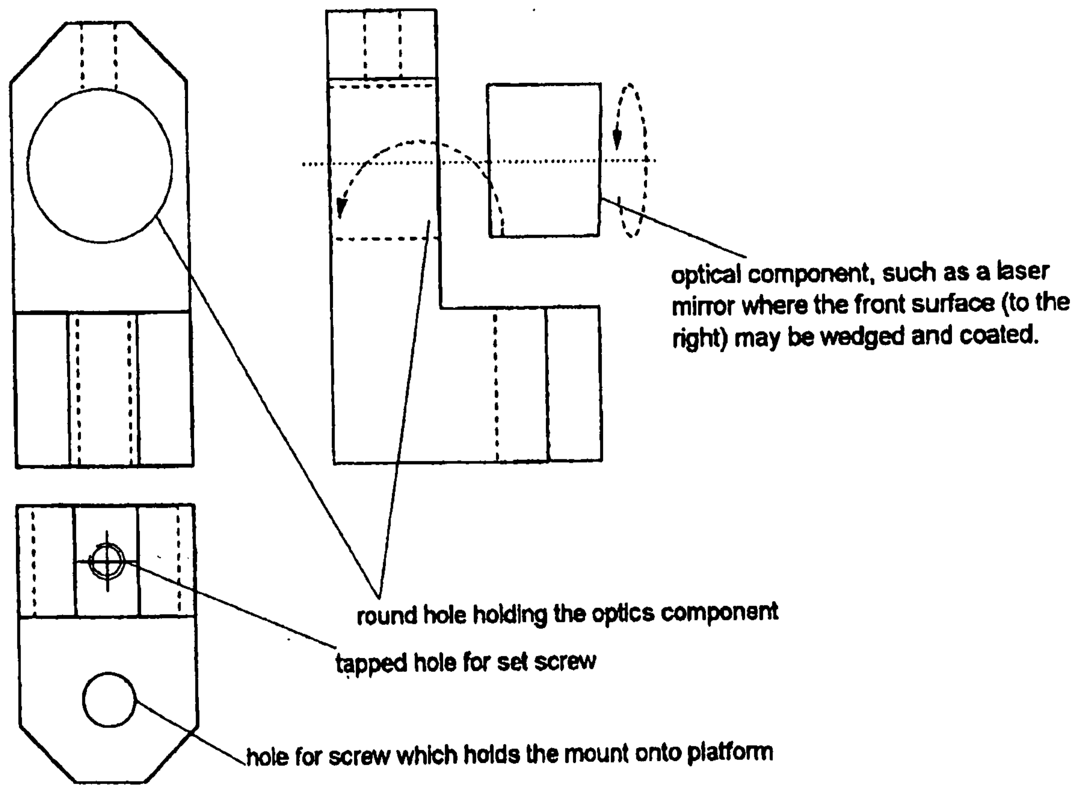


Figure 6 "LLLC - Long Life Laser Concept"